Dynamic Risers for Floating Production Systems
API Standard 2RD
Second Edition, September 2013

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deeper understanding

GENESIS

Introduction

- A new riser design code has been developed to supersede API RP2RD (1998)
- Originally developed as an ISO document by a joint ISO/API task group
- Completed as an API document
- New design criteria introduced, consistent with a limit state philosophy
- Several new sections in the revised document.
- Published September 2013

Background

1998

API RP 2RD was first issued, with industry experience mainly from TTRs for MODUs and TLPs

2003

API Standardization Committee attempted “bridging document” between 1998 API RP 2RD and 2001 DNV-OS-F201

2004

Decision to write a new ISO code instead, based on API & DNV

Significant Changes

- Evolution from working stress design to include <u>limit state</u> design methods

- New chapters:

  - Components
  - Fabrication and Installation
  - Riser Integrity Management

- New annexes:

  - Riser worked examples (SCR, TTR)
  - Supplemental design information

- Reduced size (163 pages to 81 pages)

  - Eliminated three sections
  - Cut materials section from 33 pages to 16 pages

Significant Changes (continued)

- Addressed several key design issues that presented a challenge to designers using API RP 2RD:
  - Burst (hoop stress) criterion
  - Combined loads (4 methods), any of which can be used
  - SCR touchdown stress interpretation
  - Approach to strain-based design

Limits states in API Standard 2RD

- Accidental limit state (ALS)
- Ultimate limit state (ULS)
- Serviceability limit State (SLS)
- Fatigue limit state (FLS)

Capacity of Pipe - Burst

Based on API RP 1111 formula

$$P_b = k(S+U)\ln(D/(D-2t))$$

Where

k	is equal to 0.45 for API Spec 5L or 5CT pipe
D	is the outside diameter of the pipe
t	is the nominal thickness of the pipe reduced for corrosion, wear and/or erosion as appropriate
S	is the specified minimum yield strength of the pipe
U	is the specified minimum ultimate strength of the pipe

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Burst & Wall Thickness Design

$$p_i - p_e \le F_D p_b$$

$$F_D = \begin{cases} 0.81 & \text{Production casing with tubing leek} \\ 0.81 & \text{Drilling riser with extreme pressure} \\ 0.90 & \text{Hydrostatic test} \\ 0.67 & \text{Incidental pressure} \\ 0.60 & \text{Design pressure} \end{cases}$$

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Capacity of Pipe - Collapse

- Collapse formula 1 (same as RP 2RD)

  (Accounts for elastic stability and yield stress)

$$p_c = \frac{P_y\, p_{el}}{\sqrt{P_y^2 + p_{el}^2}}$$

- **Collapse formula 2 (implicit formula from DNV)**

  (Also accounts for initial ovality and fabrication process)

$$\left(p_c - p_{el}\right)\left(p_c^2 - p_p^2\right) = p_c\, p_{el}\, p_p\, 2\,\delta_0\, \frac{D}{t}$$

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Collapse Design

$$p_e - p_i \leq F_D p_c$$

$$F_D = \begin{cases} 0.6 & \text{SLS, ULS} \quad \text{cold expanded pipe} \\ 0.7 & \text{SLS, ULS} \quad \text{seamless or ERW pipe} \\ 1.0 & \text{ALS} \end{cases}$$

Capacity of Pipe – Tension and Moment

- Tension capacity

$$\boldsymbol{T_y = SA}$$

  – where:

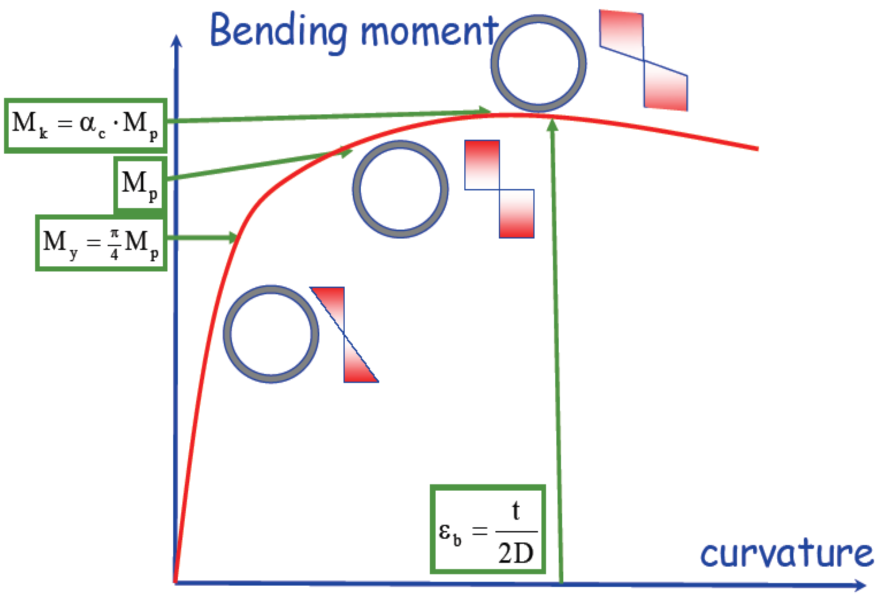
A is the pipe cross-section area

- Yield Moment

$$M_y = \frac{\pi}{4} S(D-t)^2 t$$

- Plastic moment capacity

$$M_p = \frac{4}{\pi} M_y$$



Design Methods for Combined Loads

1. Elastic (Working Stress) Design
   - Rearranges 1998 API RP 2RD
   - Relates cross-sectional T & M utilization to internal & external overpressure

$$F_D = \begin{cases} 0.80 & \text{SLS, ULS} \\ 0.90 & \text{ALS for external overpressure} > 0.5\,p_c \\ 1.00 & \text{ALS otherwise} \end{cases}$$

2. Elastic / perfect-plastic (Limit State)
   - Approach from DNV F101 and ISO 13628-7

$$F_D = \begin{cases} 0.80 & \text{SLS, ULS} \\ 1.00 & \text{ALS} \end{cases}$$

3. Plastic with Strain Hardening (Limit State)
   - DNV F201
   - LRFD, with partial safety factors

4. API RP 1111 Approach
   - Limits combined stress from axial loads and pressure
   - Imposes separate limit on bending strain

$$F_D = \begin{cases} 0.90 & \text{SLS, ULS} \\ 1.00 & \text{ALS} \end{cases}$$

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Design for Fatigue

$$\text{Damage} = \sum_{i=1}^{k} \frac{n_i}{N_i}$$

$$\text{Damage} \leq \begin{cases} 0.1 & \text{during service life} \\ 0.1 & \text{during a single ULS event} \\ 1.0 & \text{during a single ALS event} \end{cases}$$

Materials

Requirements and guidelines for

- Material selection
- Manufacture
- Testing
- Corrosion protection
- Fabrication
- Inspection
- Documentation

References DNV-RP-F201 for titanium alloys

Case Study

- X70 grade 18-inch oil export SCR
- Floater: Semi-submersible
- Location: GOM
- Water depth 2000 m
- Combined loading checks for ULS and ALS cases

Load Cases for SCR Performance Assessment

Limit state	Operational condition	Internal pressure at surface (Mpa)	Mooring condition	Offset (% of water depth)	Environmental condition
ULS	Shut-down	25	Intact	4%	100-year hurricane
ALS	Shut-down	25	One line failed	5%	100-year hurricane

Results – von Mises stress utilization

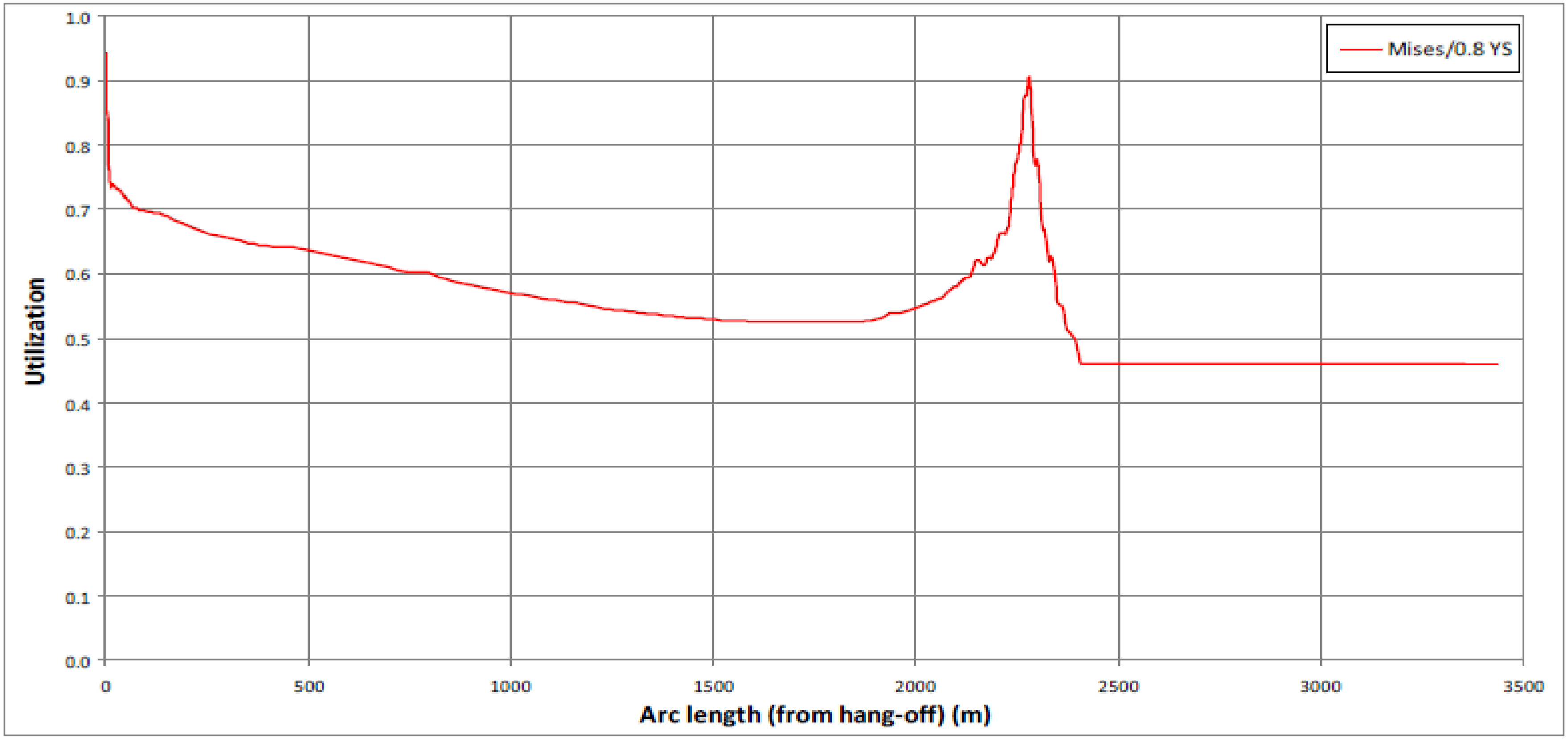
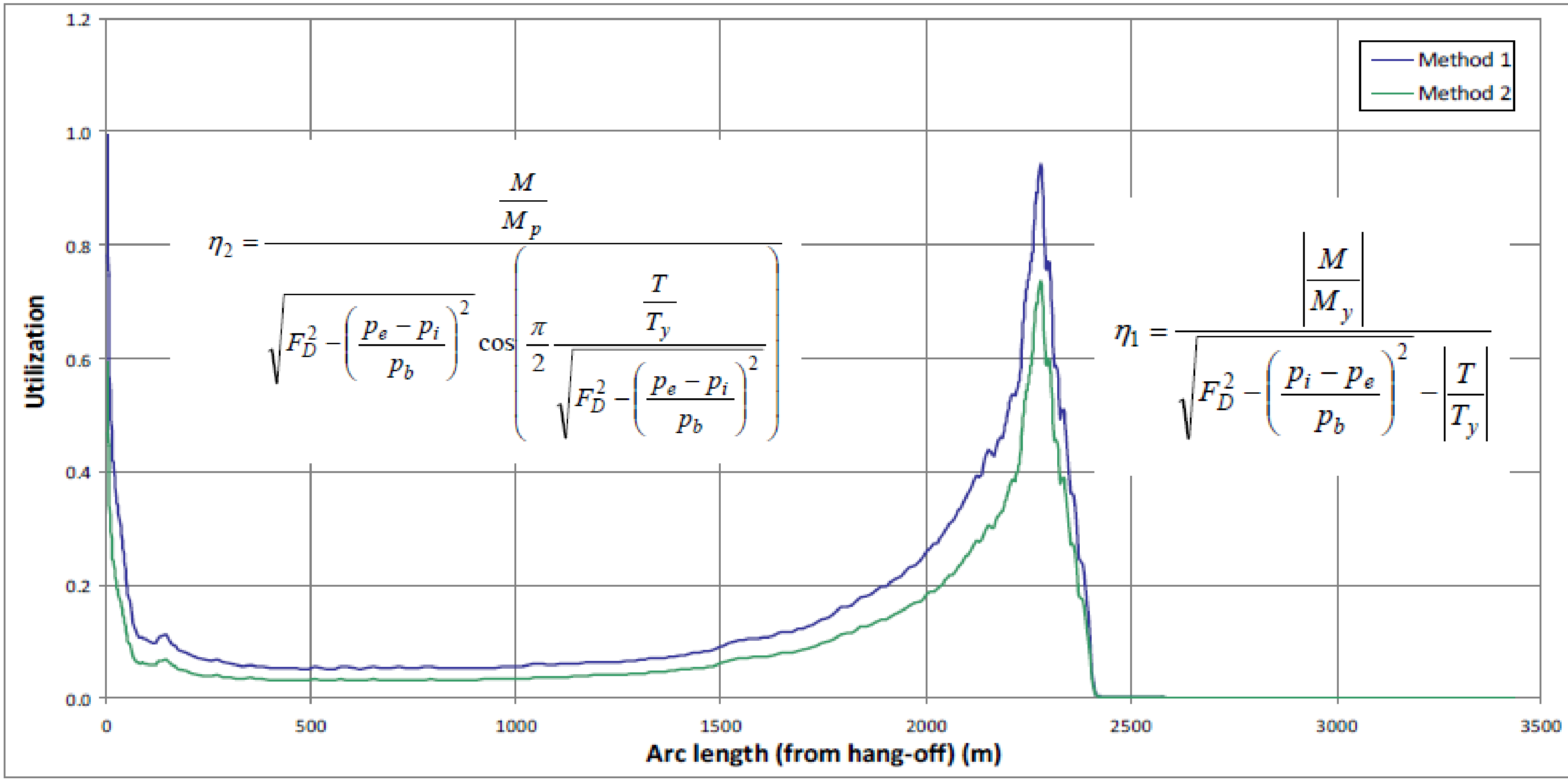


Figure 1: von-Mises stress utilization ULS case (100 yr hurricane, intact mooring)

Results – Combined loading capacity utilization



$$\eta_2 = \frac{\dfrac{M}{M_p}}{\sqrt{F_D^2 - \left(\dfrac{p_e - p_i}{p_b}\right)^2}\cos\left(\dfrac{\pi}{2}\dfrac{\dfrac{T}{T_y}}{\sqrt{F_D^2 - \left(\dfrac{p_e - p_i}{p_b}\right)^2}}\right)}$$

$$\eta_1 = \frac{\left|\dfrac{M}{M_y}\right|}{\sqrt{F_D^2 - \left(\dfrac{p_i - p_e}{p_b}\right)^2} - \left|\dfrac{T}{T_y}\right|}$$

ULS utilization based on Method 1 and Method 2

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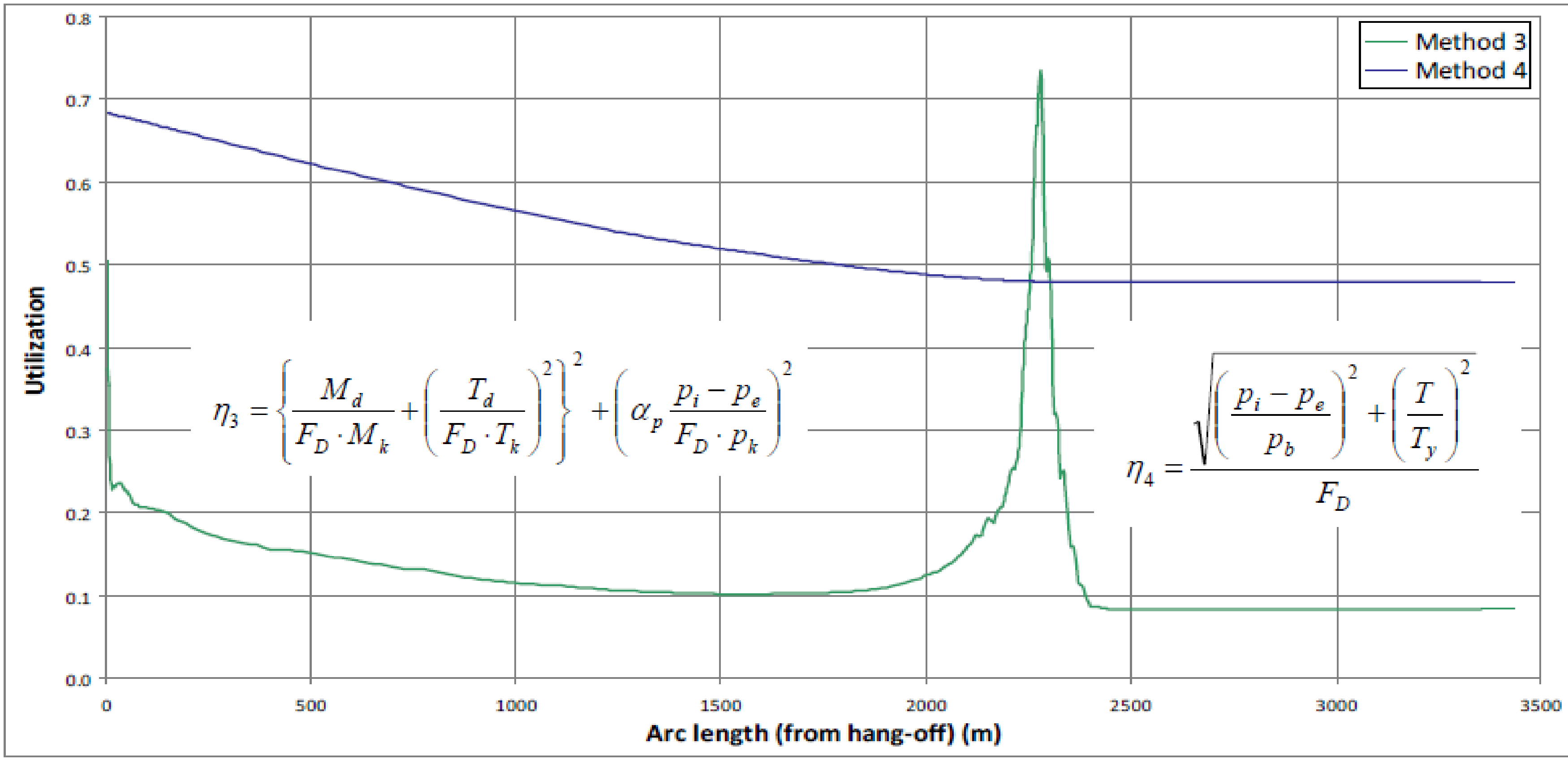
Results – Combined loading capacity utilization



$$\eta_3 = \left\{ \frac{M_d}{F_D \cdot M_k} + \left(\frac{T_d}{F_D \cdot T_k} \right)^2 \right\}^2 + \left(\alpha_p \frac{p_i - p_e}{F_D \cdot p_k} \right)^2$$

$$\eta_4 = \frac{\sqrt{\left(\frac{p_i - p_e}{p_b} \right)^2 + \left(\frac{T}{T_y} \right)^2}}{F_D}$$

ULS utilization based on Method 3 and Method 4

- Questions?